



Past, Present, and Future of the Pulse Examination (脈診 mài zhěn)

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Abstract

The pulse examination (脈診 mài zhěn) is a unique diagnostic approach of Traditional Chinese Medicine. The description of pulse examination in the history of Traditional Chinese Medicine is full of amazement and mythology. After researching in hemodynamics and investigating in clinical application for three decades, this article describes the development and the merits and demerits of pulse examination. The experiences of the ancients are tried to be illustrated with modern knowledge and language. As the theory of resonant blood circulation is discovered, Traditional Chinese Medicine could be on the shoulder of Newton and then lead the development of modern medicine. Hope the tool of pulse examination constructed according to eigen-vector with specific time domain and position can bring the running water for Traditional Chinese Medicine. Quantitative research could overcome the plight of analog logic qualitative research, and therefore bring new health revolution.

Key words: Eigen-vector, Harmonic, Spectrum, Meridian, The *Inner Canon* (內經 nèi jīng)

Foreword

The pulse examination (脈診 mài zhěn) is the symbol of Chinese medicine and also one of the features of Chinese medicine. In many writings related to Chinese medicine, the plus-taking-with-three-fingers are always considered as an important diagram. And, whenever Chinese medicine is mentioned, the image of plus-taking-with-three-fingers will come to most people's mind. Among the four examinations (also translated as 'four diagnostic methods') in Chinese medicine, the methods of inspection, listening and smelling, and inquiry have been further developed in modern medicine. Especially, regarding the method of inspection, many technologies have been rapidly developed for modern medical imaging, including X-CT, MRI, PET and ultrasonography. And the

endoscopy units, such as gastroscopy, colonoscopy, enteroscopy, as well as microscope have been all kept improved so that the scope of the method of inspection has been enlarged and becomes a medical philosophy of 'seeing is believing'. The method of listening and smelling has been developed by means of blood test and urine test, which are very convenient and affordable and therefore become basic information in all kinds of modern diagnostic.

Under the background, we start our investigation of pulse examination because, on the one hand, it is the only diagnostic method in Chinese medicine that has not yet been understood and explored in modern medicine and, on the other hand, it's our goal to further understand this valuable door to Chinese medicine.

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The Past of the Pulse Examination

According to the written history, the pulse examination is first seen in the 1st Year of Zhao Gong in the *Zuo Zhuan* (also translated as *Chronicle of Zuo*), in which documented a story about Qin Gong who sent Qin He to diagnose and treat the marquis Jin and then Qin He adopted the method of correlation of complexion and pulse to analyze his disease. The note of the *Rites of Zhou* further describes that ‘the major method to take the pulse is the wrist pulse-taking at Yang Ming, and the one who is good at this method is Qin He’. In the *History of the Later Han*, there is also a story about Pei Weng who was good at feeling the pulse and wrote a book about pulse examination and a story about Guo Yu who had great knowledge about ‘the skill of diagnosing of tiny acupoints and the art of changes between yin (陰 yīn) and yang (陽 yáng)’.

The other documents unearthed by the archaeological discoveries, such as ‘*Quicksand Falling Record Slips*’, ‘*Wuwei Han Dynasty Record Slips*’, and ‘*52 Prescriptions* (五十二病方 wǔ shí èr bìng fāng)’ are the writings earlier than the *Neijing* (also translated as *Inner Canon*) but their author were unknown. The writing that was more systematically recorded is the pulse examination of physician Bian Que, who was also named Qin Yue Ren. The ‘Collected Biographies of Bian Que and Cang Gong in *Shiji* (also translated as the *Records of the Grand Historian*)’ describe that ‘the most famous physician knowing well pulse-taking is Bian Que’. The *Huainanzi* (literally as *The Masters/Philosophers of Huainan*) also describes that he could give an appropriate prescription according to illness and diagnosed the causes of illness according to the complicated pulse.

The era of Bian Que is partially overlapped with that of the *Inner Canon* and some writings are similar to or entirely the same as the *Inner Canon* but some writings are different, such as the Ten Strange Pulses (十怪脈 shí guài mài). The most obvious difference between Bian Que and the *Inner Canon* is that the *Inner Canon* includes the ‘pulse examination of twelve meridians’ and the ‘three parts and nine indicators (三部九候 sān bù jiǔ hòu)’ but Bian Que’s pulse examination is only about the ‘exclusive examination of the inch opening (wrist pulse)’.

Bian Que attached particular importance to the changes in the pulse during a day or a year. Therefore, he proposed the principle of yin-yang pulse examination. He emphasized the regular patterns of temporal changes in three yin pulses (三陰脈 sān yīn mài)

and three yang pulses (三陽脈 sān yáng mài) and also observed the correlation between body types and pulses. Cang Gong, originally named Chun Yu-yi (淳于意 chún yú yì), a disciple-successor of Bian Que, also advocated the ‘exclusive examination of the inch opening (wrist pulse)’. According to his classification, there were twenty-two types of pulses, including floating pulse, sunken pulse, string-like pulse, rough pulse, tight pulse, slippery pulse, rapid pulse, hard pulse, replete pulse, long pulse, large pulse, scant pulse, weak pulse, normal pulse, chattering pulse, tranquil pulse, agitated pulse, dissipated pulse, intermittent pulse, foreign yin, foreign yang, and drag-over ming. Besides, the later generations often referred to his insights on febrile disease. For example, he considered that drag-over Yang pulse was the intermingling of yin and yang and the most threatened illness of double contraction and described it as ‘heat relapses after sweating, agitated racing pulse and incessant sweating, manic raving with inability to eat.’ As to drag-over yin pulse, he described it as ‘recovering with normal and clear pulse’. His insights were used in other classics, such as the “Plain Questions, Treatise Discussing Heat Disease” and Zhang, Zhong-jing’s *Cold Damage* ‘the first day of cold damage is the cold damage of tai yang and if the pulse is tranquil, it is non-passage.’

Although Cang Gong thought that none of the four examinations was less important than the others, he stressed particularly the method of pulse examination as he mentioned ‘so many similar diseases difficult to be known, that’s why the ancient sages adopted the method of pulse-taking. It’s a measurement and a rule to balance, to regulate and adjust yin and yang. The pulses of human body were named according to the rules of heaven and earth. Meanwhile, by considering an individual’s constitution, we could tell hundred diseases.’

He not only referred to many ancient medical documents, such as pulse examination, pulse examination principles, diagnosis (診法 zhěn fǎ), and odd cough, but he also had some outstanding disciples, such as Song Yi, Du Xin, and Tang An, who had contributed much to the succession of the knowledge of pulse (脈學 mài xué).

According to the documents ‘*Central Treasury Canon* (中藏經 zhōng zàng jīng)’, ‘*Divine Physician Hua Tuo’s Secret Tradition*’, ‘Ways to observe visceral pathological changes’, we could know that Hua Tuo’s (華佗 huà tuó) pulse examination method was inherited from Bian Que, that is, his diagnostic method was also ‘exclusive

examination of the inch opening (wrist pulse)'. For the first time, corresponding relation between the 'inch, bar, and cubit' and the various organs were noticed, such as the heart, the small intestine at left inch, the liver and gallbladder at left bar, the kidney at left cubit, the lung at right inch, and the spleen at right bar. As for the other parts, no documents were available for reference.

When Cang Gong adopted the 'exclusive examination of the inch opening (獨取寸口 dú qǔ cùn kǒu, wrist pulse), he didn't tell the difference between 'inch, bar, and cubit' and he pressed with two or three fingers jointly. And, his pressing method included only floating pulse and sunken pulse. Until Hua Tuo, he proposed the method of 'three fingers and three parts', that is, we could press with three fingers jointly or with one finger singly. The "pulse examination about organs" had been well developed. As to the organs not indicated, it is believed that the related documents might have been lost. Hua Tuo also proposed the 'pulse examination with eight principles', including yin and yang pulses, exterior and interior pulses, cold and heat pulses, and vacuity and repletion pulses, as an equivalent work to the 'pulse examination about organs'.

The pulse examination of the *Inner Canon* originated from one school of the 'medical classics (醫經 yī jīng)'. The *Inner Canon* is the first written record among the 'medical classics' handed down to the later generations until today and it is the most important work among the medical classics. It not only integrates the ancient pulse examinations, such as the sphygmology theory of Bian Que, that of Cang Gong, and that of Hua Tuo, but it also plays the role as successor of the past and as pioneer of the later generations and it still works as the basis of the backbone of Chinese medicine.

The content of the *Inner Canon* is the collection and collation of the relevant medical knowledge during the Warring States Period and the Qin and Han Dynasties. The main structure is composed of 'yin and yang', 'five phases (五行 wǔ xíng)', 'organs (臟腑 zàng fǔ)' and 'meridians (經絡 jīng luò)' and forms a thoroughly integrated classic work that no others have surpassed today. Regarding the discourses of sphygmology theory, however, there were no consistent arguments in respect of the principles, methods, pulses and main diseases so that an inclusive way was adopted to deal with those issues.

In the *Inner Canon*, the <Plain Questions, Treatise on the Three Parts and Nine Indicators> was actually the result of the evolution and development of the pulse examination of twelve meridians. The sphygmology theory of the *Inner Canon* is based on 'yin and yang' and

considers the 'meridians' as blood vessels. It considers the blood passes through the 'twelve meridians' (rather than the 'blood vessels' commonly called today) so that a pulse examination is to inspect and diagnose the distribution of blood inside a human body. For example, the normal one is called as 'normal pulse (平脈 píng mài)' and the unusual one is called as 'morbid pulse'. In the perspective of the *Inner Canon*, it is clearly stated that a pulse examination is to inspect the 'meridians'. For the examination of the 'meridians', we could inspect directly the points of artery on the 'meridians' and we also could distinguish the 'twelve meridians' or 'three parts and nine indicators' through the artery at the inch opening (wrist pulse). It is also the basis on which the pulse examination has been developed by the later generations. And, the *Pulse Canon* (脈經 mài jīng) by Wang, Shu-he (王叔和 wáng shū hē), which includes the theory about the inch opening divided into nine ways and that about the subordinate meridians belonging to 'inch, bar, and cubit (寸關尺 cùn guān chǐ)', becomes the mainstream of sphygmology in the later generations. However, for Zhao, En-jian, a modern great sphygmology master, 'one of the major problems is that there was no succession or development of the ideas, methods and contents of the generalized examination of the whole body. And, that is the main reason why pulse examinations were not greatly developed by the later generations. Otherwise, a generalized examination of the whole body should have been significantly developed; for such a long time and through such a large number of practices, the method of 'palpation' should have been completely developed in all aspects; and, for these two thousand years, in the practice of Chinese medicine, the touch parts should not only have been focused on the radial artery while inspecting a patient'. (Chao, 1988)

Summary

As for the old documents about pulse examination, the *Inner Canon* had completely collated their main contents so that the later physicians only took the summarized parts in the framework of the *Inner Canon*. Some parts were somehow further developed but some parts got lost. Such a phenomenon is frequently seen in the development of Chinese culture. Until the modern time, there have been always some people, just like Wang Mang of the New (Han) Dynasty, who advocate everything should return to and follow the ancient classics and culture. It's the same as Chinese medicine; some people also advocate everything should return to

and follow the medical knowledge documented in the *Inner Canon* and the classical remedy of Zhang Zhong-jing and other ancient physicians.

After a review, in all aspects, of the features of Chinese culture, a very interesting viewpoint is found.

Logic system of Chinese culture is always about analogy. All 'yin and yang', 'five phases', 'I Ching Hexagrams' and 'twenty-eight pulses in pulse examination' had been developed their qualitative description according to the method of analogy and been mostly described in text. We find not only the operational definition but also the concept of quantization was absent. An ancient at that time, probably Bian Que or a genius of earlier era, found the functions of the human body could be explained by analogy with 'yin and yang', 'five phases', metal, wood, water, fire, and earth. Meanwhile, another genius found the phenomena of astronomy and four seasons could be explained by analogy with metal, wood, water, fire, and earth. What an earth-shattering discovery!

Within Chinese culture, the harmony between man and nature has been greatly advocated. According to the *Inner Canon*, within the human body we could find the existence of a small universe of heaven, earth and man. It is a work exemplifying Chinese culture.

We reviewed this logic system of analogy, that is, all things in the whole world could be explained by 'yin and yang' and 'five phases' and then we got an idea.

Among the things in the world that have been recorded, most of them are periodic. That's because the non-periodic things or matters had flashed off and we have not had another chance to observe them. Accordingly, we have not had chance to obtain a detailed record about them. Therefore, it will be difficult to be kept in our history and culture.

The sunrise, sunset, change of four seasons, cycle of astrological phenomena and so on were all clearly observed by and known to the ancient civilizations around the world. That the Egyptians worshiped the sun or that the Mayan people understood astrological phenomena and could predict the date of occurrence of a solar eclipse or a lunar eclipse thousands of years later are obvious examples. And, the Chinese, Mayan, Egyptian civilizations all have their perpetual calendar. What a great achievement!

Within the ancient Chinese culture, the ancients created 'yin and yang' and 'five phases' to describe the relationship between all things in the world. At first glance, this five-element culture seems quite the same as the four-element culture of Greece or the six-element

culture of the Hebrew, but what is more interesting is that the 'mutual engendering and subduing' derived from the five-element culture could be explained by the harmonic waves that were composed of periodic signals.(Wang 2002, Wang et al. 1989)

About 70% to 80% of this five-element culture of 'mutual engendering and subduing' could be explained by the relationship of 'mutual engendering and subduing' between the harmonic waves.

With 70% to 80% of correctness, workable for all periodic things, it was used in the *Inner Canon* to explain the cyclical phenomena in physiology, that is, the features of pulse waves. Because the heart has been repeatedly beating, the pulse waves accordingly generated could be described by the 'mutual engendering and subduing' of 'five phases' to achieve 70% to 80% of correctness. It was really a great achievement during the era in which physiology was still unknown.

Therefore, within Chinese medicine, the various theories derived from the logic system of analogy allowed our ancients to tell the types of diseases and determine the treatments directly without the help of anatomy or physiology, without understanding cytology or the functions of each organ, and without having any knowledge of the distribution of endocrine, nerves or blood vessels. It is the power of the logic system of analogy! And, it is the great wisdom of the ancient sages!!

However, the analogy relationship not only lacks the total accuracy but also presents only the similarity of an analog. The biggest drawback of the logic system of analogy is the lack of quantified data. Because of lack of analysis of quantified data, no accurate verifications could be carried out. The ancient sages realized this great analogy relationship two or three thousand years or more years ago. If the later generations still limited their ideas in this analogy relationship, they would never start the work of verification using quantified data only because they limited their understanding or they wanted to expand the scope of application without taking consideration the overall situation. That's why the right ways, evil ways, truths and lies all have been present in the documents since the Qin and Han Dynasties.

What on Earth Does the Pulse Examination Inspect?

1. Twelve meridians on the whole body:

A) Pulse examination of twelve meridians: a method

to choose an emerging or relatively emerging pulsating vessel that is exemplifying or easy to be inspected, among the twelve meridians, including three yin channels of the hand, three yang channels of the hand, three yin channels of the foot, three yang channels of the foot, to inspect the pulsating vessel (vessel qi). The exact locations are as follows:

Great Abyss (太淵 tàiyuān): lung, inch opening (wrist pulse).

Yang Ravine (陽溪 yángxī): large intestine, union valley of the hand.

Surging Yang (衝陽 chōngyáng): stomach, dorsum of the foot.

Surging Gate (衝門 chōngmén): spleen, front and rear groove joints at the bottom of the belly.

Yang Pore: heart, inside Spirit Gate.

Celestial Window (天窗 tiānchuāng): small intestine, beside the throat.

Bend Center (委中 wěizhōng): bladder, bent part of the back of the knee.

Great Ravine (太溪 tàixī): kidney, side point on the inner face of the ankle.

Palace of Toil (勞宮 láogōng): colorful network vessel, palm heart.

Harmony Bone-Hole (和髎 héliao): triple burner, between the eye and the ear.

Suspended Bell (懸鐘 xuánzhōng): gallbladder, on the outer face of the ankle.

Supreme Surge (太衝 tàichōng): liver, upper surface of the great toe of the foot.

In the early stages of the creation of pulse examination, the diagnoses were carried out through the twelve meridians on the whole body.

In the history of the development of Chinese medicine, the most mysterious part is the twelve meridians. Among the earliest written records, i.e. the document unearthed at Mawangdui, we could find the eleven channels, except for heart channel. Until the *Inner Canon*, we could find all the twelve meridians. It's unlike the pulse examination or prescriptions, of which the development process could be traced through the documents.

The generalized examination of the whole body through the twelve meridians is more comprehensible. The purpose of the pulse examination is to understand the distribution of qi and blood (pulse) inside the twelve meridians on the whole body. Therefore, if the distribution is found particularly large or small, it must be a sign of disease. The distribution should be uniform or even, the pulse could be determined as a

normal pulse, i.e. a regular pulse. In the perspective of the idea of the *Inner Canon*, the pulse examination is to inspect the distribution of blood inside the channels and diseases could generate uneven distributions inside the twelve meridians. Therefore, the pulse examination is to diagnose the health condition of the meridians. Besides, the twelve meridians belong to yin, i.e. the geometric structure of the distribution of blood; and, the pulses belong to yang, i.e. the vibrations generated by the blood flows inside the twelve meridians. After having understood the principles of the pulse examination, we could understand the meridians; on the contrary, if we could make a breakthrough in the study of the meridians, we could understand the pulse examination. They are the both sides of the same integrated body.

2. Three parts and nine indicators:

B) Pulse examination of three parts and nine indicators: as for this method, please refer to <Plain Questions, Treatise on the Three Parts and Nine Indicators>. The exact locations are as follows:

Heaven at upper part: the arterial of the cheeks, foot lesser yang channel (少陽經 shàoyángjīng) on the both sides of the forehead.

Earth at upper part: the arterial of the cheeks, on the both sides of the nose closer to Great Bone-Hole yang brightness channel.

Man at upper part: the arterial in front of the ears, hand lesser yang channel at the sunken part in front of the ears.

Heaven at central part: hand greater yin, inch opening (wrist pulse).

Earth at central part: hand yang brightness, union valley.

Man at central part: hand lesser yin, spirit gate.

Heaven at lower part: foot reverting yin, the sunken part that is one-inch outside pubic hair region and under sheep bar, about five li and find it at prone part; for the females, take great thoroughfare, i.e. the sunken part that is two-inch behind the base joint of the great toe of the foot.

Earth at lower part: foot lesser yin, at the sunken part of the anklebone on the inner side of the foot, great ravine.

Man at lower part: foot greater yin, on fish belly (魚腹 yúfù) and between rush sinews, under rigid five li and about winnower gate (箕門 jīmén); find it by loosening the feet, with simple clothing and feeling the deep level; after examining stomach qi, find it on the upper surface of the foot and about surging yang.

The *Inner Canon* goes to great length to show the ‘Three parts and nine indicators’. Many modern physicians consider it’s actually the same method as the pulse examination of twelve meridians and it’s also a generalized examination of the whole body and it does not have much specific meanings.

3. Inch, bar, and cubit (寸關尺 cùn guān chǐ):

Taking pulse on radial artery has been always the symbol of Chinese medicine. The wrist pulse-taking method began as early as Bian Que’s era. The organs had been clearly classified as early as Hua Tuo’s era. For example, left inch included heart and small intestine, left bar included liver and gallbladder, left cubit included kidney; right inch included lung, right bar included spleen. Stomach pulse was classified as over-bar but the specific position of over-bar was not indicated. In the later generations, however, a slight difference appeared but the principal structure was generally maintained, always on the basis of Hua Tuo’s classification. The relationships between ‘left inch, left bar, left cubit, right inch, right bar, right cubit’ and organs were collated in respect of the important ancient documents as Table 1.

After the construction of the tool of pulse examination from 1988 to 1990, we had carried out many partial

measurements, specified at inch, bar, and cubit. The sensors were respectively installed at the positions of ‘inch, bar, and cubit’, or at the position a little more in front of ‘inch’ or a little more in back of ‘cubit’. The pulses obtained from the left hand were within the margin of error, in other words, they were almost with the same value. And, the pulses obtained from ‘inch, bar, and cubit’ of the right hand showed the same result, that is, they were almost the same.

This result is somewhat unexpected. In the perspective of hemodynamics, however, it seems inevitable. That’s because when the blood in the arteries moves from the proximal end of heart to the remote end of heart, both blood pressure wave and blood fluid wave are continuous, and how could a significant change occur in such a section of blood vessel less than 5 cm? Unless a significant change at the positions of “inch, bar, and cubit” is presence in such a section of artery or surrounding tissues. In order to save Chinese medicine, some people proposed a fractal theory and considered that this small section of blood vessel and its surrounding tissue can reflect the structure of the other parts or organs of the human body. But both for the normal and ill persons, no specific change is found in this small section of blood vessel and its surrounding

Table 1. The relationships between ‘left inch, left bar, left cubit, right inch, right bar, right cubit’ and organs Name of work

Name of work		Inch		Bar		Cubit	
		Left	Right	Left	Right	Left	Right
The <i>Inner Canon</i>	Inner	heart	lung	liver	stomach	kidney	kidney
	Outer	chest center	in th chest	diaphragm	spleen	abdomen	abdomen
The Classic of Difficult Issues (難經 nán jīng)		heart	lung	liver	spleen	kidney	pericardium
		small intestine	large intestine	gallbladder	stomach	bladder	triple burner
The <i>Pulse Canon</i> (脈經 mài jīng)		heart	lung	liver	spleen	kidney	kidney
		small intestine	large intestine	gallbladder	stomach	bladder	bladder triple burner infant’s door
Pulse Formula		heart	lung	liver	spleen	kidney	life gate
		small intestine	large intestine	gallbladder	stomach		
Thousand Golden Pieces Formulary		heart	lung	liver	spleen	kidney	kidney
Bin-Hu Sphygmology (瀕湖脈學 bīn hú mài xué)		heart	lung	liver	spleen	kidney	life gate
		chest	central	diaphragm	lower	umbilicus	lower
Indispensable Medical Reading (醫宗必讀 yī zōng bì dú)		heart	lung	liver	spleen	kidney	kidney
		pericardial network	in the chest	spleen	stomach	bladder	large intestine
Three-finger meditation		heart	lung	liver	spleen	kidney	life gate
Jing-Yue’s Complete Compendium (景岳全書 jǐng yuè quán shū)		heart	lung	liver	spleen	kidney	Kidney
		pericardial network	chest center	gallbladder	stomach	bladder	triple burner
Pulse treatment		heart	lung	liver	spleen	kidney	life gate
		small intestine	large intestine	gallbladder	stomach		
Truth-Seeking Pulse Theory		heart	lung	liver	spleen	kidney	kidney
		chest center	in the chest	gallbladder	stomach	bladder	triple burner
						small intestine	life gate
							large intestine

tissue.

While carrying out a pulse examination, a physician uses three fingers on the positions of ‘inch, bar, and cubit’ to feel the vibration of the pulse on these positions carefully. This is the so-called pulse-taking in Chinese medicine.

As for the definition of the positions of ‘inch, bar, and cubit’, the most often used one is about the positions around the wrist where is located the radial artery. On the outer side of the wrist, there is a piece of protruding bone, the position of which is named as ‘bar’. The position, which is closer to the side of palm and about one finger away from the palm, is named as ‘inch’. The position, which is closer to the side of heart and about one finger away from the palm, is named as ‘cubit’. This definition is for both right and left hands. Therefore, they are the mirror image to each other.

The sensors were respectively installed at the positions of ‘inch, bar, and cubit’ to measure the wave of pulse. The waveforms were almost identical. But the waveforms of the right hand were not totally the same as the ones of the left hand.

We can’t help but ask : Is it a mistake, the three-finger knack that has been used for three thousand years ? Are they illusions, the debates about the five viscera and six bowels ?

We carried out again and again the pulse-taking on the positions of ‘inch, bar, and cubit’ with fingers and we also carried out the pulse-taking by using the pulse examination instruments and sensors. After having thought about this issue several times, we finally obtained some clues. They are not yet the answers but they can provide an idea as reference.

The inch opening pulse has nine tracts, that is, in modern language, the pulse waves at inch opening pulse are composed nine harmonic waves. In addition to the radial artery, we also obtained some pulse waves at other arteries. Interestingly, the pulse waves at inch opening pulse are very easy to be obtained. Perhaps, it’s the main reason why the ancients chose the pulse waves at inch opening pulse.

Another feature of the pulse examination of inch opening (wrist pulse) is the composition of 0-11 harmonic waves and the vibration amplitude and is inversely proportional to the number of harmonics. From the 0th harmonic, the vibration amplitude of the harmonic waves the more behind is smaller. Of course, it is the pulse obtained from normal persons. For the ill persons, the energy of the corresponding vibration amplitude of the ailing meridians or organs may become

smaller or larger. For the seriously ill persons, the vibration amplitude may be smaller than the next or next two harmonic waves.

That the vibration amplitude becomes smaller and smaller with the increase of the number of harmonic waves allows us to know the relationship between the vibration amplitudes : heart (0) > liver (1) > kidney (2) > spleen (3) > lung (4) > stomach (5) > gallbladder (6) > bladder (7) > brain (8) > triple burner (三焦 sān jiāo) (9) > small intestine (10).

The number inside the brackets behind the name of organ is the number of harmonic waves of the corresponding pulse wave of each organ, for example, the heart presents the 0th harmonic wave and the liver presents the 1st harmonic wave and so forth.

If a pulse wave is divided into three sections in respect of the timeline, the upper section mostly tends to present the 0th and 4th harmonic waves (because the lung and liver subdue each other, the 4th harmonics wave could be more obviously observed in the upper section) (Wang 2002, 2011). The middle section presents the 1st, 3rd and 5th harmonic waves and the lower section presents the 2nd harmonics wave. Here we only take into consideration the 0th to 5th harmonic waves, i.e. the six largest harmonic waves obtained at the inch opening (wrist pulse).

If the pulse examination of the positions of ‘inch, bar, and cubit’ is not to obtain the absolute vibration amplitude of each position but the wave spread on the positions of ‘inch, bar, and cubit’ when it passes through the inch opening (wrist pulse), that is, the position of ‘inch’ corresponds to the upper section of pulse wave, the position of ‘bar’ corresponds to the middle section, and the position of ‘cubit’ corresponds to the lower section.

From this, the position of ‘inch’ corresponds to heart or lung. The position of ‘bar’ corresponds to spleen, stomach or liver and the position of ‘cubit’ corresponds to kidney. This is similar to the conclusion obtained by the ancients.

Floating, middle and sunken techniques:

The ‘sunken pulse in floating pulse’ is another myth in the pulse examination in Chinese medicine. Since ancient times, this technique has been attached importance to in the documents of pulse examination. However, when we used the sensors to measure the pulse wave on the radial artery, we found that pulse wave diagram obtained using more pressure is similar to the one using less pressure. Similarly, the results of the measurement on the positions of ‘inch, bar, and cubit’

are similar to each other. In this case, how could we tell the difference with fingers?

Actually, precisely speaking, it's not correct to say the pulse wave obtained using more pressure is similar to the one using less pressure. Using too much pressure, the blood pressure wave would be blocked and the lower part of the pulse wave would disappear. Using too little pressure, the sensors would not be well attached to the artery and some details of pulse wave would be concealed. However, within a reasonable range, no more than diastolic blood pressure, no less than 20mmHg (a slight difference might occur depending on the response of sensors), the pulse waves measured by using the floating, middle and sunken techniques can't be distinguished to the naked eye.

We also proposed some modern ideas, as a reference, in respect of this traditional technique used in the pulse examination in Chinese medicine. The pulse-taking with fingers depends on the sensitive tactile sensation of fingers so the arms or palms are not suitable for it. No matter how sensitive the fingers are, the tactile sensation is after all a physiological response. In the studies of physiological feelings, there is a well-known theory called 'Weber-Fechner Law' found by Weber and Fechner. They discovered that in the transformation of the neural signals by a sense organ, there would be a transformation of logarithm.

If the size of signal is X and the reaction of nerve is Y , we can find $Y = A \log X$ and A is a constant. This relationship can be expressed in another form as $\Delta X / X = C$ and C is a constant, that is, if our sense organ detects an external signal with strength X , the strength that our sense organ could distinguish will be ΔX so that $\Delta X = CX$. In other words, where $C = 1 / 10$, when a weight of 10 kg is measured by hand, the weight could be distinguished will be 1 kg; and, when a weight of 10 g is measured by hand, the weight could be distinguished will be 1 g.

After having understood this rule of physiological response, we investigated the possible intention of the floating, middle and sunken techniques. If little pressure is used, with only 10 g, the vibration change of 1 g will be distinguished. If more pressure is used, with 100 g, the vibration change of 10 g will be distinguished. In the section about 'inch, bar, and cubit', we have mentioned the vibration amplitude of each harmonics wave A is as follows: $A(C0) > A(C1) > A(C2) > A(C3) > A(C4) > A(C5) > A(C6) > A(C7) > A(C8) > A(C9) > A(C10)$. Among the pulse waves measures at the inch opening (wrist pulse), the harmonics wave with higher frequency

has smaller vibration amplitude.

According to the relationship $\Delta X / X = C$, it can be inferred that it needs to obtain the vibration amplitude of the harmonics wave with lower frequency. That's because ΔX is larger, a larger X could be used in order to obtain a C with the same value. In the case with a larger X , the vibration change of the harmonics wave with higher frequency is ΔZ and $\Delta Z < \Delta X$; and, the physiological response obtained is D and $D \ll C$. As a result, in the case with a larger pressure (sunken technique), the feeling perceived by the fingers in respect of the harmonics wave with higher frequency will be passivated.

Another physiological phenomenon to be taken into consideration is that five viscera belong to yin and their harmonics wave are as follows: C0 (heart), C1 (liver), C2 (kidney), C3 (spleen), C4 (lung). All of them are with low frequency. Slow ones are viscera and rapid ones are bowels. And, C5 (stomach), C6 (gallbladder), C7 (bladder), C8 (large intestine), C9 (triple burner), C10 (small intestine). All of them are with high frequency.

The ones with low frequency will change slowly and the ones with high frequency will change rapidly. Where a little pressure (floating technique) is used, the changes of the five viscera in a short time will be smaller than the ones of the six bowels because the pulse of the five viscera changes slowly and the pulse of the six bowels changes rapidly. Therefore, if the floating technique is used to take pulse, the small and rapid changes could be easily perceived, that is, the resonance wave of the bowels.

From this, the ancients must have studied seriously. Indeed, if we carefully distinguish and deliberate the relationships between the different pressures used by fingers, the magnitude of the changes of pulse wave as well as the speed of the changes of vibration amplitude, we could distinguish the significant changes of vibration amplitude of some viscera or bowels.

Twenty-eight pulses and viscera-bowel pulses :

In the documents of pulse examination, the most emphasized ones are the twenty-eight pulses. And, in the prespective of practicability, the twenty-eight pulses may be easier to get started than the viscera-bowel pulses.

However, the twenty-eight pulses and the viscera-bowel pulses always coexist. One is easy to get started and to be learned and the other contains more information but is less easy to be obtained.

The twenty-eight pulses are signals of analog. Therefore, they are described as follows: string (弦

xián) -like pulse means the pulse is like a string; tight (緊 jǐn) pulse means the pulse presents an intensity; slippery (滑 huá) pulse means the pulse presents no resistance; rough (澀 sè) pulse means the pulse presents a large resistance and so forth. All are mainly described with words. According to the judgment by intuition, the twenty-eight pulses should be the collective change of pulse wave at the moment of the occurrence of a certain disease of the viscera or bowels. For example, in the sections about disease distinguishment and treatment argument in the nowadays textbook of Chinese medicine, the pulse examination has been always considered as a way to distinguish diseases. Among the exogenous diseases, for example, the externally contracted (外感 wài gǎn) wind-cold presents: the pulse is floating and tight (exterior repletion) or floating and moderate (exterior vacuity); the pulse is floating and tight but forceful (exterior repletion and internal heat, severe cold and heat); the pulse is floating and tight (exterior cold and internal rheum); the pulse is floating and rapid (at the beginning of warm disease); the pulse is floating and slightly surging (externally contracted wind-cold, cold depression transforming into heat).

All these are used to facilitate the distinguishment of the symptoms that may occur at the moment of an exogenous cold. But it can't facilitate the distinguishment of the affected area, including the channel, bowel and viscera.

That's because the floating pulse, rapid pulse, surging pulse and tight pulse are easier to be perceived. It's unlike the viscera-bowel pulses that need profound studies of the details of 'inch, bar, and cubit' or 'floating, middle and sunken techniques' and make people get lost easily on the contrary. This is also the result of the practical development of modern Chinese medicine in terms of diagnostics.

After having used the modern equipments and understood many details of the changes in pulse wave, how should we deal with or make use of these two similar but different and coexisting methods of pulse examination?

In modern sciences, Matrix A is often used to quantify the linear relationship between two things or states. For example, $Y = AX$.

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} x_1 & x_2 & x_3 & x_4 \end{bmatrix}$$

It is used to indicate the relationship between Y ($Y_1 Y_2 Y_3 Y_4$) and X ($X_1 X_2 X_3 X_4$) is a matrix of order 4. It is used to indicate the linear relationship between four things or states. To indicate the linear relationship between n things or states, it needs to use a matrix of order n. In project economics, the famous Slutsky Matrix or Substitute Matrix could be used to quantify exchange value between the products or international trade. This Matrix is also used to quantify the situation of genetic changes. In physics, quantum mechanics also used this relationship to quantify energy levels of electrons (eigen--value) in an atom and its orbit (eigen-vector).

Moreover, in statistics, this matrix is the standard method used to quantify the correlations between two things and states.

In linear algebra, this matrix depends on the choice of the basis used to expand the states, and can have the most simple form through reductionism. Firstly, it needs to find the eigen-vectors of A. These eigen-vector must be orthogonal. When states are expressed in the eigen-space, Matrix A is then diagonalized.

Therefore, in finding the quantified relationships between some things or states, the most important step is to find the suitable orthogonal basis to express the states. Thus, if we want to find the relationships between the pulse examination and physical health, we must find the suitable orthogonal functions to expand the pulse wave.

After several years of research, we found the various harmonic waves with frequencies equal to the integer multiples of the heart rate are the simplest basis-functions; and the physical health can be examined quantitatively through the Fourier Transform of the pulse pressure P (t). We also derived a blood pressure wave propagation equation and found the generalized eigen-vectors of the equation (Lin Wang et al. 2008).

Furthermore, interestingly, after having carried out many experiments, we found that the eigen-frequencies of the axial position dependent part of the pressure wave equation are strongly correlated with the natural frequencies of the organs and the integer multiples of the heart rate. And, the harmonic Fourier components of the pulse wave could be used to quantify the health status of the correlated organs, meridians (Lin Wang et al. 2010).

In this process of research and development, the most surprising and grateful thing, is how our ancestors found the meridians and how they knew the resonance waves of the meridians were eigen-vectors.

So far, the advantages and disadvantages of the examination of viscera-bowel pulses and twenty-eight pulses are very clearly presented. The twenty-eight pulses are signals of analog. It's an accommodated method of measurement generated under the predicament of the pulse-taking only with fingers, which can't allow us to totally understand the physical health and can't be quantified.

Let's review the 'pulse examination of twelve meridians' and the 'three parts and nine indicators' proposed in the *Inner Canon*, they are the so-called the generalized examination of the whole body.

According to the *Inner Canon*, it is considered the distribution of the blood pressure wave is based on the 'twelve meridians' and standardized in accordance with the rules of the 'three parts'.

Although this diagnostic method was not adopted in the works by the later physicians, such as in the *Pulse Canon* by Wang Shu-he, and was not spread accordingly, this theory was unlike the one about 'inch, bar, and cubit' which generated many different opinions and endless arguments. Not only are there many different opinions about the corresponding viscera and bowels but also more arguments about the definition of the positions of 'inch, bar, and cubit'. If a phenomenon has been the subject of polemic for more than two thousand years, it must have some problems.

In contrast, that the pulse examination can allow us to know the physical health of the 'twelve meridians' has been the consensus for several thousand years. The arguments between many famous ancient physicians are only about how to choose the best points of measurement, how to define the points of measurement and how to analyze the signals obtained from these points of measurement.

During the period of our study of the pulse examination, although some famous biomechanics scholars questioned the pulse examination and some scholars engaged in the research of the signals of pulse examination also published a number of articles, none of them provided any significant discovery (Wang et al. 1977, 1978, 1980; Wei and Chou 1985).

Since the analyses of the signals of pulse examination only proved that the pulse examination with three fingers at the positions of 'inch, bar, and cubit' seemed difficult to provide the information about the physical health of the various organs or meridians, we started with the study of the distribution of blood to the 'twelve meridians' and their corresponding organs.

After having carried out the studies of the simulation

of circulatory system by using balloons and water pipes and the studies of the arteries around the kidney and spleen of rats, we finally found the phenomenon of resonance in the blood circulatory system (Lin Wang et al., 1991, 2010). This theory provides not only a more precise method of measurement for the pulse examination but also a clear definition for the mysterious meridians, i.e. the core structure of Chinese medicine.

According to the generalized examination of the whole body proposed in the *Inner Canon*, we can infer the distribution of qi and blood of the human body is not completely laissez-faire. After the heart pushes the blood through the aortic valve, the blood pressure wave does not advance passively and the blood does not move ahead totally by itself. And, the theory about the moving ahead of blood by itself is the phenomenon of blood circulation introduced in the modern physiology. 'All arteries and organs are passive components like resistors'. Besides, owing to lack of a good understanding of the circulatory system, the prevalence of chronic diseases, such as hypertension, cardiovascular disease, cerebrovascular disease, diabetes, and diseases caused by the function degradation of lung or other organs has become a modern killer. And, for these diseases, there are mostly some conservative treatments for the symptoms and no fundamental rehabilitation therapies. Therefore, it needs to take medicine for more than a decade or even for decades.

(I) the whole body- pulse examination of twelve meridians:

Generalized examination:

After having understood more about the pulse examination by using modern scientific tools, we reviewed all the traditional pulse examinations mentioned previously. By using the theory of resonant blood circulation, it would be easier to understand the generalized examination of the whole body, i.e. the pulse examination of twelve meridians. Every channel or vessel is the highway for the transportation of a certain blood pressure wave's harmonics wave in the human body. The twelve meridians and vessels allow the twelve harmonics to move to the corresponding organs and the resonant organs with the same harmonics. As long as the blood is sent to the organ or acupuncture point, it only needs to make a tiny opening on the artery of such organ or acupuncture point, the blood will go into the surrounding tissues. It's like a tire full of air, a tiny opening on which can allow the air to go out. For

an artery full of blood, any tiny opening on which can allow the blood to flow out. From this phenomenon of resonant blood delivery, we could know that if the high-speed transportation highway is damaged, its ability to deliver the blood will become worse. Since the blood pressure wave sent to the organ or acupuncture point is damaged, the pulse wave of the organ or acupuncture point will disappear accordingly. That means the organ and meridians will get weak at the same time, that is, they will get sick. And vice versa, if the organ gets sick, the feature of resonance will diminish and then interfere in the blood delivery of the meridians; and, some changes in the vibration of the corresponding pulse wave will be generated, too. Therefore, through the vibration on the acupuncture point of the twelve meridians, we could know the situation of the blood delivery of the organs, meridians and then make the correct diagnosis.

(II) Three parts and nine indicators:

In the *Inner Canon*, we could find many records about the ‘three parts and nine indicators’. That means the ancients attached particular importance to them but they were not handed down to the later generations. Cheng, Zhong-ling, a later physician, pointed out that ‘there are tips for pulse examination, that is, only the three words: Stomach, Spirit, and Root’. It seems the essence of the ‘three parts’ is obtained.

1. Stomach: the *Inner Canon* indicates that ‘stomach is the regular qi of a normal person’. Zhang Jing-Yue developed its meaning by mentioning that ‘stomach qi is a person’s yang qi. If yang qi gets weak, stomach qi will become weak. If yang qi gets vanquished, stomach qi will become scattered. It is the basic sign of life’.

2. Spirit: Zhang Jing-Yue mentioned that ‘the one who is good at pulse examination will particularly observe the spirit, not the form. If one observes the form, he will not find the important clue because the form has thousands of shapes. If one observes the spirit, he could find the unique essence and unique reality’.

3. Root: the *Classic of Difficult Issues* mentions that ‘if upper part has no pulse and lower part has pulse, it will be cumbersome but not harmful and could become better naturally. A person having cubit pulse is like a tree having roots. Although the branches and leaves are withered, the roots will grow naturally.’ Therefore, whether a person has the root pulse is an important sign of the absence, exuberance and debilitation of qi in the kidney. “A physician must know” ‘two cubit is the position of kidney, six pulses of sunken indicators are

related to kidney’. Actually, this viewpoint is directly connected to the three parts. Stomach is to diagnose the middle part (man), Spirit is to diagnose the upper part (heaven) and Root is to diagnose the lower part (earth).

When we were measuring the three acupuncture points at the upper part, we found the 6th harmonics was larger than great abyss (the inch opening (wrist pulse)) by dozens of percentage points (%). It shows that the upper part of the human body presents common resonance frequency, that is, the 6th harmonics. By using the same method, we found that the 2nd harmonic was the common resonance frequency after having compared the three acupuncture points at the lower part to the inch opening (wrist pulse). Similarly, after having compared the three acupuncture points at the middle part to the ones at the upper or lower parts, we found the 4th harmonic was larger by dozens of percentage points (%). It shows that the 4th harmonic was the common resonance frequency at the middle part (Wang et al. 1989).

From this experiment, we could know that the three parts in the ‘three parts and nine indicators’ have a special physiological significance. They should present the resonance frequency of the blood vessels of the head (the 6th harmonic), the resonance frequency of the blood vessels of the hand (the 4th harmonic), and the resonance frequency of the blood vessels of the foot (the 2nd harmonic). If we measure the distance from the heart to the head, from the heart to the hand, and from the heart to the foot, we also find that the proportion is 1:2:3. Therefore, it is a reasonable inference that the three parts present the resonance frequency of the measured blood vessels. All these were proven by experiments. And, the ‘twelve meridians’ all have their respective corresponding harmonics; for the special applications of this theory in respect of diagnosis and treatment, please see (Wang 2002, 2011).

Pulse Examination, Disease, and Prescription

In the *Inner Canon* and Zhang Zhong-jing’s works, the pulse examination and the diseases are connected through carefully deliberate and distinguish the onset and process of an illness and the pathology. In the *Pulse Canon* by Wang Shu-he, in order to highlight the status of the pulse examination, the correspondences between the pulses and the diseases were dealt with directly. A single corresponding relationship between a pulse and a disease was built. And, even for the prescriptions, many single corresponding relationships were built. For example, if the pulse over bar is slightly floating

and accumulated heat is in the stomach, there should be vomiting of roundworm and heart forgetfulness; if the pulse over bar is tight and slippery, there should be roundworm; if the cubit pulse is sunken and slippery, there should be inch white worm; if the pulse is felt at eight inch and goes to fish border, there should be enuresis. Moreover, in the 3rd text about the manifestations of disease and the treatments of the normal three bars, the single corresponding relationships between a pulse and a treatment prescription were built. As to the so-called roundworm or white worm or enuresis, if we use the method of modern scientific proof to prove these is no roundworm or white worm or enuresis, could we prove that the *Pulse Canon* is incorrect?

The *Pulse Canon* almost used the method of exhaustion to include all kinds of possibilities to build the one-to-one correspondence between the pulses at the parts of 'inch, bar, and cubit' and twenty-four pulses and all kinds of diseases. It seems that we could never see so many kinds of changes and so many kinds of diseases during ninety years for three lives. It is obvious that the single corresponding relationships built in the *Pulse Canon* were a game of permutations and combinations rather a collection of written records of clinical experiences.

In our point of view, this book is the best error sample of Chinese culture. The ancient sages found an analogy relation and then many interpretations were generated to express the analogy relation between two systems. Naturally, it's impossible to obtain a complete deduction of the distribution of blood of the twelve meridians and network vessels by using 'yin and yang' and 'five phases'. Only 70% to 80% of correctness could be achieved.

And, the later generations didn't carry out any verification but infinitely expanded this analogy relation instead. There are inevitably many unbelievable mistakes. As to the herbal foundation and formula study, because they were not confused by the documents of the pulse examination, they became the fields with more development in Chinese medicine since the Qin and Han Dynasties. Because there were always some experiments on human body and some plagues, the physicians could not help but face the reality and seriously face the consequences and correct the errors with a practical and realistic attitude. Therefore, after the Han and Jin Dynasties, there were some Chinese medicine and prescription masters, such as Sun Si-miao (孫思邈 sūn sī miǎo) and Li Shi-zhen (李時珍 lǐ shí zhēn). On the contrary, both the basic Chinese medicine

theory according to twelve meridians and network vessels and the Chinese medicine diagnosis according to the pulse examination become a chaos and go back to the dawn of the beginning of the world. However, the examination of the tongue has made substantial progress in Chinese medicine because it is easy to perform and verify.

The Future of the Pulse Examination

The development of a science should be continuously verified. The great British philosopher Francis Bacon was the advocate of verifications and he was also the founder of modern experimental science. He advocated to carry out verifications by using newly invented tools. Although he also emphasized the method of induction as a means of advancing sciences, he always emphasized the method of verification in the induction process. Especially, he suggested that people should correct the bad habits in a variety of sciences and inexplicable worship of idols that he considered as the biggest obstacles to the advances in technology.

He mentioned four kinds of worship of idols:

1) idols of the Tribe:

The instinct of human cognition might cause some distortions of things and these distortions become part of the common knowledge among human beings. That the misuse of the concept of 'yin and yang' and 'five phases' in Chinese culture generated a culture like the Yihetuan Movement (also known as Boxer Uprising) is a terrible example.

2) idols of cave:

It refers to any theory that is developed according to an individual's personal limited experiences or personal belief or imagination. For example, some religious figures or Qigong masters always consider they are particularly blessed and have extraordinary supernatural or magic powers.

3) idols of market place:

It refers to the power by word of mouth or by word of the public to make the wrong become the right. That the large-scale rallies during the election campaigns in Taiwan that cause the opposition between the blue and green electors is the best example of the use of idols of market place by the politicians.

4) idols of theater:

The world is actually a theater. The past experiences and all kinds of knowledge were accumulated in the

textbooks, books, films and novels. If the knowledge were not proven, it may be a wrong display or performance. We must be prudent. And the singers and movie stars created in our time are exactly the typical idols of theater.

If we want to maintain these worships of idols, they must be proven right and they will be worthy of being worshiped.

Before the era of Bacon, there was no obvious difference of economy and civilization between the East and West. The economy and civilization of the West was mainly located in Italy in Europe. And the economy and civilization of the East was in China. Owing to the expansion of the influence of Bacon, the center of the civilization of the West was moved to the United Kingdom and then the Industrial Revolution was generated and the British Empire was built. The development of the economy and civilization of the West started to get separated from the religions but achieved magnificent results in the Industrial Revolution by bringing the fruits of science and technology to daily life and daily productions.

Bacon's philosophy facilitated the leaps and bounds in the development of the economy and civilization of the West. Can it provide something for us to learn?

The present article makes use of it sincerely to submit some suggestions here for the future development of the pulse examination.

It is suggested to use objective tests (tools) and inductive method as the rules to verify all past or new theories of the pulse examination. It is suggested to develop new analysis about the diagnoses of all kinds of physical conditions and the treatments of all kinds of diseases. It is suggested not to follow the rules of interpretations of the pulse examination (as used in the *Pulse Canon*), which only used the method of exhaustion to include all kinds of possibilities without any verification or inductive method.

After having carried out a large number of experiments, we proposed a tool for the pulse examination as the basis of further verifications and also as the beginning of distillation. And, in respect of the basic Chinese medicine theory, we also integrated the definition of twelve meridians and network vessels and the principles of the pulse examination.

We only proposed a pulse examination instrument as a tool that was produced according to the physiological basic data about the twelve meridians and network vessels after the verifications and inductions. This objective tool, without depending on the sense of touch

of fingers, can be provided as the beginning point of the future development of the pulse examination. Because it is entirely mechanical operation, the data could be easily represented. Because the operation is simple, the verification becomes easy. Because it doesn't depend on the sense of touch, there is no subject judgment and no need to conduct a long-term training or learning, it can become very popular easily. Because the same phenomena also happen to animals, a great part of the verifications could be carried out through animal experiments to improve the efficiency of verification.

It is suggested to investigate the function of a certain remedy according to the principles of the pulse examination in order to develop the new prescriptions to cure various prevalent modern diseases, especially the metabolic chronic diseases.

It is suggested to make use of the principles of the pulse examination to verify the active ingredients of a certain remedy through animal experiments. It is suggested to make use of the principles of the pulse examination to investigate, through animal experiments, the pharmacology of Chinese medicine that is helpful for the improvement of blood circulation of a certain organ. These are a number of specific directions provided as an initial step to start new discussions, even in new directions.

Let's jointly participate in and look forward to a new health revolution, as the Industrial Revolution, to launch another brand-new phase of human civilization.

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